Networking with Linux®
on System z

SHARE Orlando – Session 9267

02/28/08

Steffen Thoss (thoss@de.ibm.com)

IBM Development Lab, Boeblingen, Germany

Trademarks

The following are trademarks of the International Business Machines Corporation in the United States and/or other countries.

Enterprise Storage Server
ESCON*
FICON
FICON Express
HiperSockets
IBM*
IBM logo*
IBM eServer
Netfinity*
S/390*
VM/ESA*
WebSphere*
z/VM
zSeries

* Registered trademarks of IBM Corporation

The following are trademarks or registered trademarks of other companies.

Intel is a trademark of the Intel Corporation in the United States and other countries.

Java and all Java-related trademarks and logos are trademarks or registered trademarks of Sun Microsystems, Inc., in the United States and other countries.

Lotus, Notes, and Domino are trademarks or registered trademarks of Lotus Development Corporation.

Linux is a registered trademark of Linus Torvalds.

Microsoft, Windows and Windows NT are registered trademarks of Microsoft Corporation.

Penguin (Tux) compliments of Larry Ewing.

SET and Secure Electronic Transaction are trademarks owned by SET Secure Electronic Transaction LLC.

UNIX is a registered trademark of The Open Group in the United States and other countries.

All other products may be trademarks or registered trademarks of their respective companies.

Agenda

- Linux 2.6 device model
- Linux on System z network device drivers
- Configuration of network devices
  - SUSE SLES10
  - RedHat RHEL5
- Channel Bonding
- VLAN

Linux 2.6 Device Model

- Integrated uniform device model that reflects a system's hardware structure
- Simplified device reference counting and locking
- Unified user interface via sysfs
  - **Hierarchical, tree-like** representation of system's hardware
  - Several subsystems provide **different views** of the hardware
  - **Configuration of devices via attribute files**
  - **Dynamic attach/detach** of devices possible

Linux 2.6 Device Model (cont.)

```
/sys
|--block
|   |...
|--bus
|   |...
|--class
|   |...
|   |--net
|   |...
|--devices
|   |...
|...
```

Block subsystem (view):

Block devices and partitions (dasda, ram0)

Bus subsystem (view):

Device drivers and devices sorted by bus (ccw)

Class subsystem (view):

Logical devices sorted by type, i.e. to which class they belong;

Logical devices have link to hardware device

Devices subsystem (view):

All the devices of a system

Linux 2.6 Device Model – System z Examples

```
/sys
|--block
|   |--dasda
|   |...
|--bus
|    |--ccw
|    |--ccwgroup
|    |    |--devices
|    |         |--0.0.a000
|    |    |--drivers
|    |         |--lcs
|    |         |--qeth
|    |              |--0.0.a000
|    |--css
|--class
|    |--net
|         |--eth0
|              |--device
|--devices
     |--qeth
          |--0.0.a000
```

Block Devices:

DASD, RAM-Disk, Minidisk

SCSI, Loopback

CCW Group Devices:

QETH, LCS

Example: a QETH device

Many ways to find a device

Linux for System z Network Device Drivers

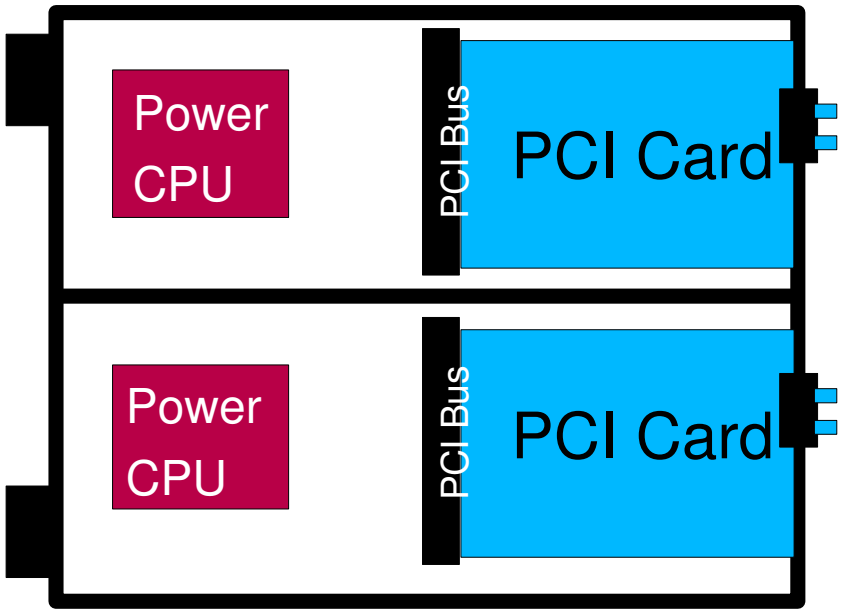
- QETH
- LCS
- CTC (stabilized)
- NETIUCV (stabilized)

QETH Device Driver

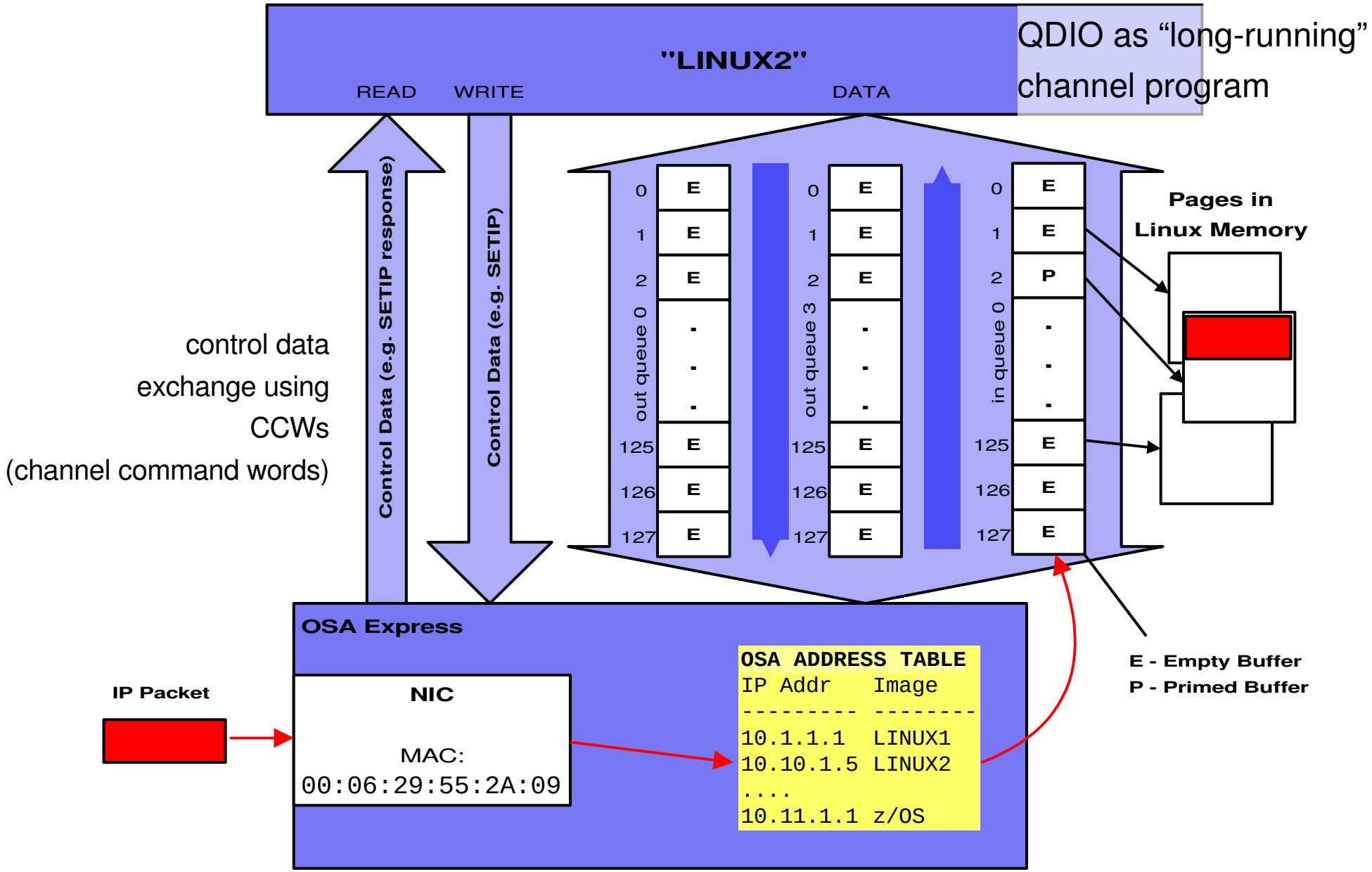
- Includes support for:
  - OSA Express(2) - Fast/Giga/10GBit Ethernet
  - 1000Base-T Ethernet
  - Highspeed Tokenring
  - ATM (running Ethernet LAN Emulation)
  - z/VM GuestLAN Type QDIO (layer2 / layer3), Type Hiper
  - z/VM VSWITCH (layer2 / layer3)
  - System z HiperSockets
- IPv4, IPv6, VLAN, VIPA, Proxy ARP, IP Address Takeover, Channel Bonding
- **Primary network driver for Linux on System z**
- **Main focus in current and future development**

Primary Network Device: OSA Express

- 'Integrated Power computer' with network daughter card
- Shared between up to 640 / 1920 TCP/IP stacks
- OSA Address Table: which OS image has which IP address
- Three devices (I/O subchannels) per stack:
  - Read device (control data <-- OSA)
  - Write device (control data --> OSA)
  - Data device (network traffic)
- Network traffic Linux <--> OSA
  at IP or ARP level
- One MAC address for all stacks
- OSA handles ARP
  (Address Resolution Protocol)



The Queued Direct I/O (QDIO) Architecture



LCS Device Driver

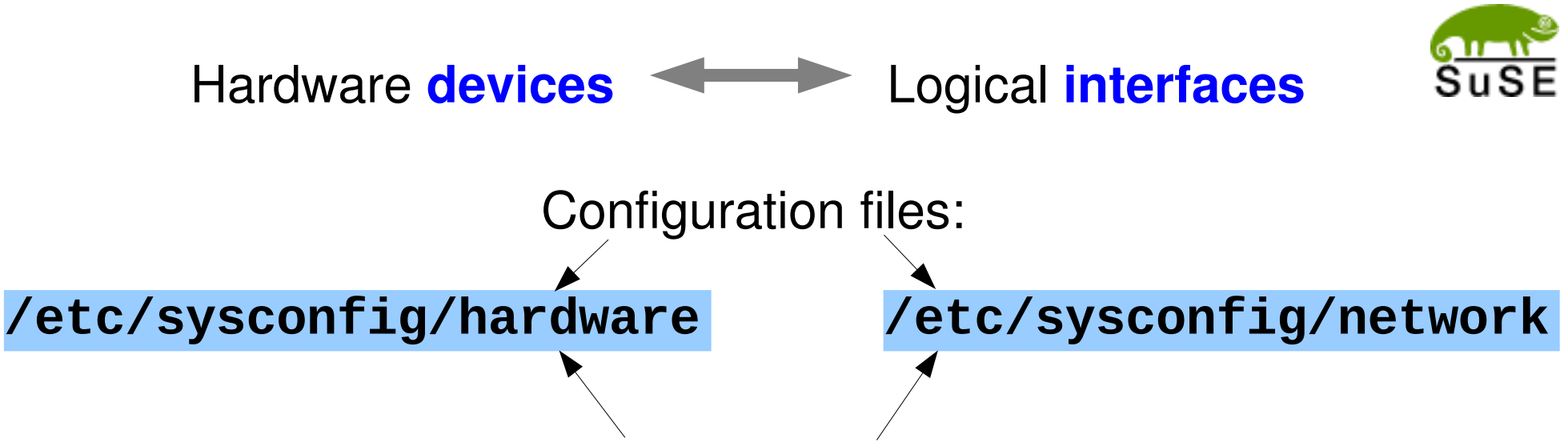
- LCS – LAN Channel Station
- Supports:
  - OSA-2 Ethernet and Tokenring
  - OSA-Express Fast Ethernet, 1000Base-T Ethernet (z890 and z990) and Highspeed Tokenring
    (in non-QDIO mode)
  - Since z990: OSA-Express 2 Gigabit Ethernet
    (in non-QDIO mode)
- May be preferred instead of QETH for security reasons
  - Administrator defines OSA Address Table, whereas with QETH each Linux registers its own IP address --> restricted access

But: performance is inferior to QETH's performance!!!

Message to CTC and IUCV users

- CTC = Channel-to-Channel connection
- IUCV = Inter User Communication Vehicle
- CTC and NETIUCV device drivers are deprecated (LINUX 2.6+)
- Device drivers still available for backward compatibility
- Migrate
  - Virtual CTC and IUCV to guest LAN Hipersockets or guest LAN type QDIO
  - CTC inside a CEC to Hipersockets
  - CTC to OSA-Express (QDIO)

SUSE SLES 10 Network Configuration



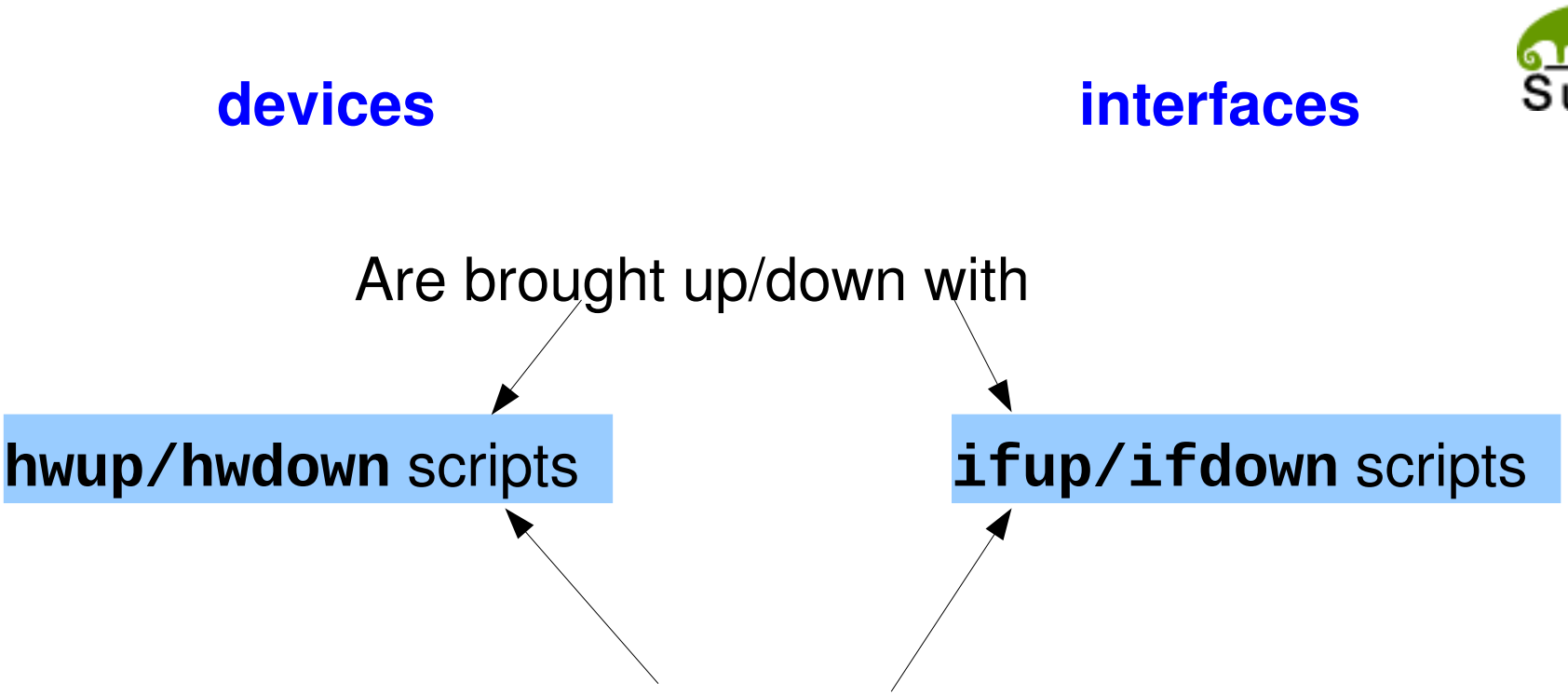
Naming convention:

hw/ifcfg-<device type>-bus-<bus type>-<bus location>

e.g. **hwcfg-qeth-bus-ccw-0.0.a000**
ifcfg-qeth-bus-ccw-0.0.a000

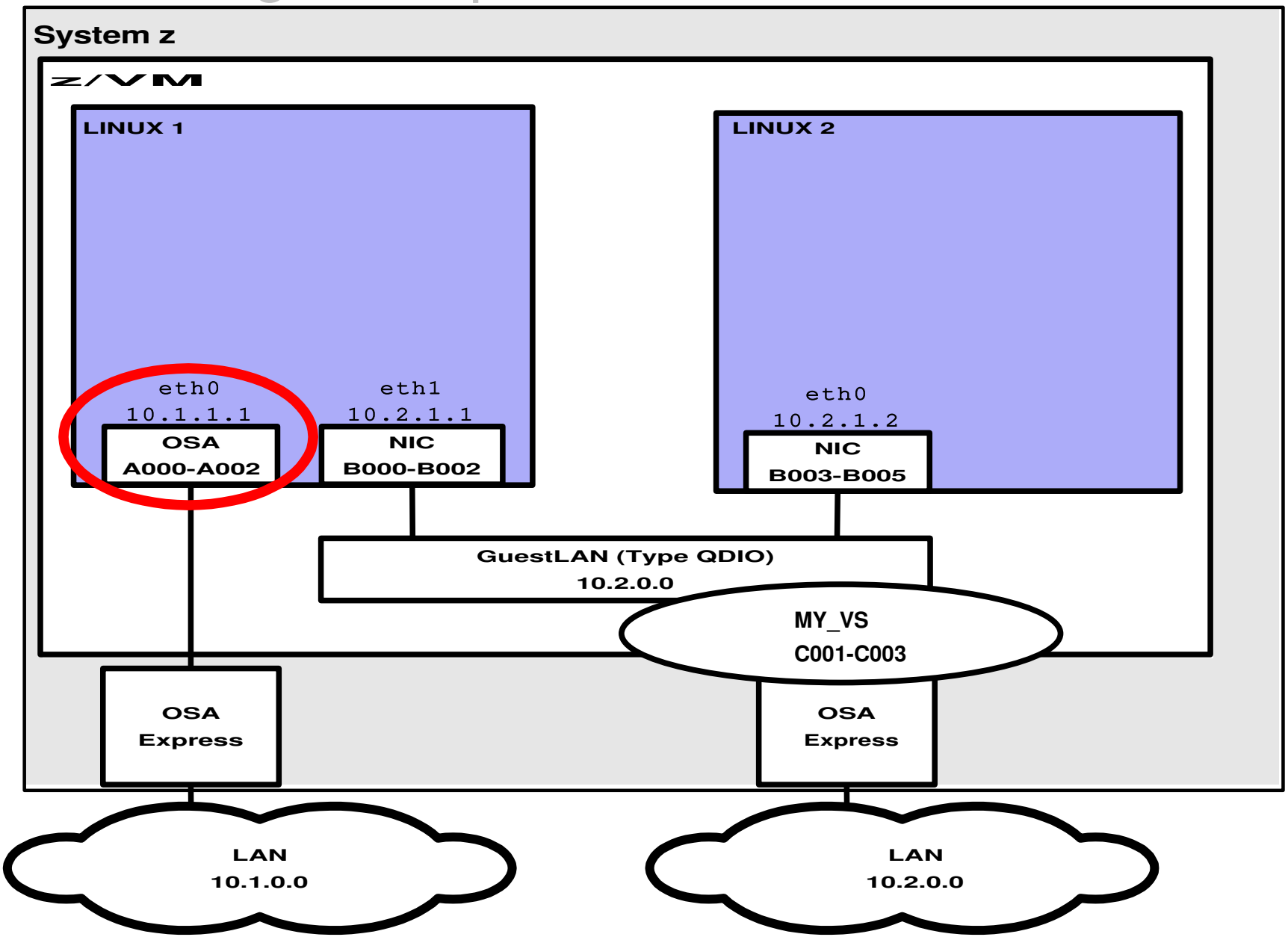
see **/etc/sysconfig/hardware/skel/hwcfg-<device type>**

SUSE SLES 10 Network Configuration (cont.)



See also: /usr/share/doc/packages/sysconfig/README and README.s390

Networking Example

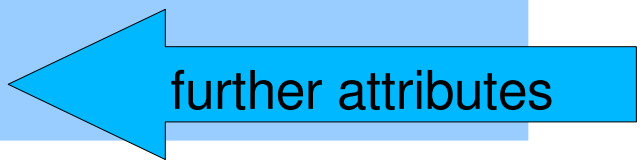


Static QETH Device Setup (SUSE SLES10)

For LINUX 1 eth0

1. Create a hardware device configuration file:

```
/etc/sysconfig/hardware/hwcfg-qeth-bus-ccw-0.0.a000:
  CCW_CHAN_IDS='0.0.a000 0.0.a001 0.0.a002'
  CCW_CHAN_MODE='OSAPORT'
  CCW_CHAN_NUM='3'
  MODULE='qeth'
  MODULE_OPTIONS=''
  MODULE_UNLOAD='yes'
  SCRIPTDOWN='hwdown-ccw'
  SCRIPTUP='hwup-ccw'
  SCRIPTUP_ccw='hwup-ccw'
  SCRIPTUP_ccwgroup='hwup-qeth'
  STARTMODE='auto'
  QETH_LAYER2_SUPPORT='0'
  QETH_OPTIONS='fake_ll=1'
```



Static QETH Device Setup (SUSE SLES10) (cont.)

- **CCW_CHAN_IDS** are Read, Write, Data subchannels
  - Hexadecimal characters must be lowercase
- **STARTMODE** 'auto' --> started by hotplug agents
  'manual' --> manual startup
- **QETH_OPTIONS** allows to set optional attributes

  e.g. `QETH_OPTIONS='fake_ll=1'`

- A sample hwcfg-file for QETH can be found at `/etc/sysconfig/hardware/skel/hwcfg-qeth`

Static QETH Device Setup (SUSE SLES10) (cont.)

2. Create an interface configuration file:

```
/etc/sysconfig/network/ifcfg-qeth-bus-ccw-0.0.a000
  BOOTPROTO='static'
  BROADCAST='10.1.255.255'
  IPADDR='10.1.1.1'
  NETMASK='255.255.0.0'
  NETWORK='10.1.0.0'
  STARTMODE='onboot'
```

Explanations are found in

```
/etc/sysconfig/network/ifcfg.template
```

3. Before reboot: test your config files:

```
#> hwup qeth-bus-ccw-0.0.a000
```

RedHat RHEL5 Network Configuration

- Configuration files:

/etc/modprobe.conf

```
alias eth0 qeth
alias eth1 qeth
alias hsi0 qeth
alias eth2 lcs
```

/etc/sysconfig/network-scripts/ifcfg-<ifname>

```
NETTYPE       qeth | lcs | ctc | iucv
TYPE        Ethernet | CTC | IUCV
SUBCHANNELS  0.0.b003,0.0.b004,0.0.b005
PORTNAME
OPTIONS
MACADDR
```

- **ifup/ifdown** scripts contain mainframe-specifics

Static QETH Device Setup (RedHat RHEL5)

For LINUX 1 eth0

1. Create the configuration file:

```
/etc/sysconfig/network-scripts/ifcfg-eth0:
  DEVICE=eth0
  SUBCHANNELS='0.0.a000,0.0.a001,0.0.a002'
  PORTNAME=OSAPORT
  NETTYPE=qeth
  TYPE=Ethernet
  BOOTPROTO=static
  ONBOOT=yes
  BROADCAST=10.1.255.255
  IPADDR=10.1.1.1
  NETMASK=255.255.0.0
  MACADDR='00:09:6B:1A:9A:89'
  OPTIONS='layer2=1'
```

further attributes

Static QETH Device Setup (RedHat RHEL5) (cont.)

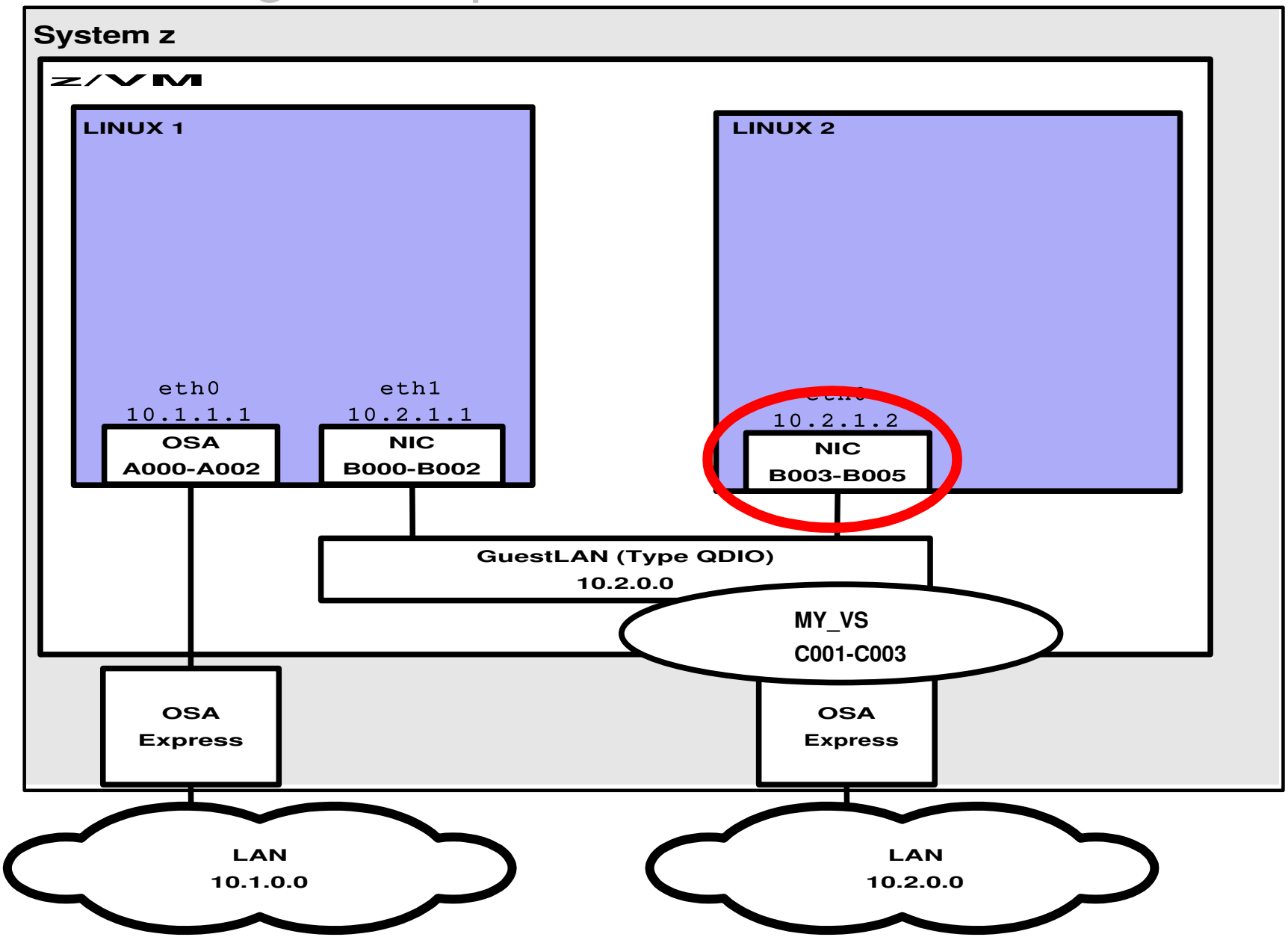
2. Add / verify alias in /etc/modprobe.conf:

```
/etc/modprobe.conf:
   ...
   alias eth0 qeth
   ...
```

3. For details see:

http://www.redhat.com/docs/manuals/enterprise/

Networking Example



Dynamic QETH Device Setup

For LINUX 2 eth0

1. In your z/VM console (if not already defined in user directory) do

    1.1. Create a GuestLAN or VSWITCH

```
#CP DEFINE LAN MY_LAN TYPE QDIO

#CP DEFINE VSWITCH MY_VS RDEV C001 CONTROLLER * IP
```

    1.2. Create a virtual NIC

```
#CP DEFINE NIC B003 TYPE QDIO
```

    1.3. Couple virtual NIC to GuestLAN/VSWITCH

```
#CP COUPLE B003 TO * MY_LAN
```

Dynamic QETH Device Setup (cont.)

2. Load the QETH device driver module:

```
#> modprobe qeth
```

3. Create a new QETH device by grouping its CCW devices:

```
#> echo 0.0.b003,0.0.b004,0.0.b005 > /sys/bus/ccwgroup/
   drivers/qeth/group
```

4. Set optional attributes:

```
#> echo 64 > /sys/bus/ccwgroup/drivers/qeth/0.0.b004/
   buffer_count

#> echo 1 > /sys/devices/qeth/0.0.b004/fake_ll
```

Note the alternative ways to your device

Dynamic QETH Device Setup (cont.)

5. Set the new device online:

```
#> echo 1 > /sys/devices/qeth/0.0.b004/online
```

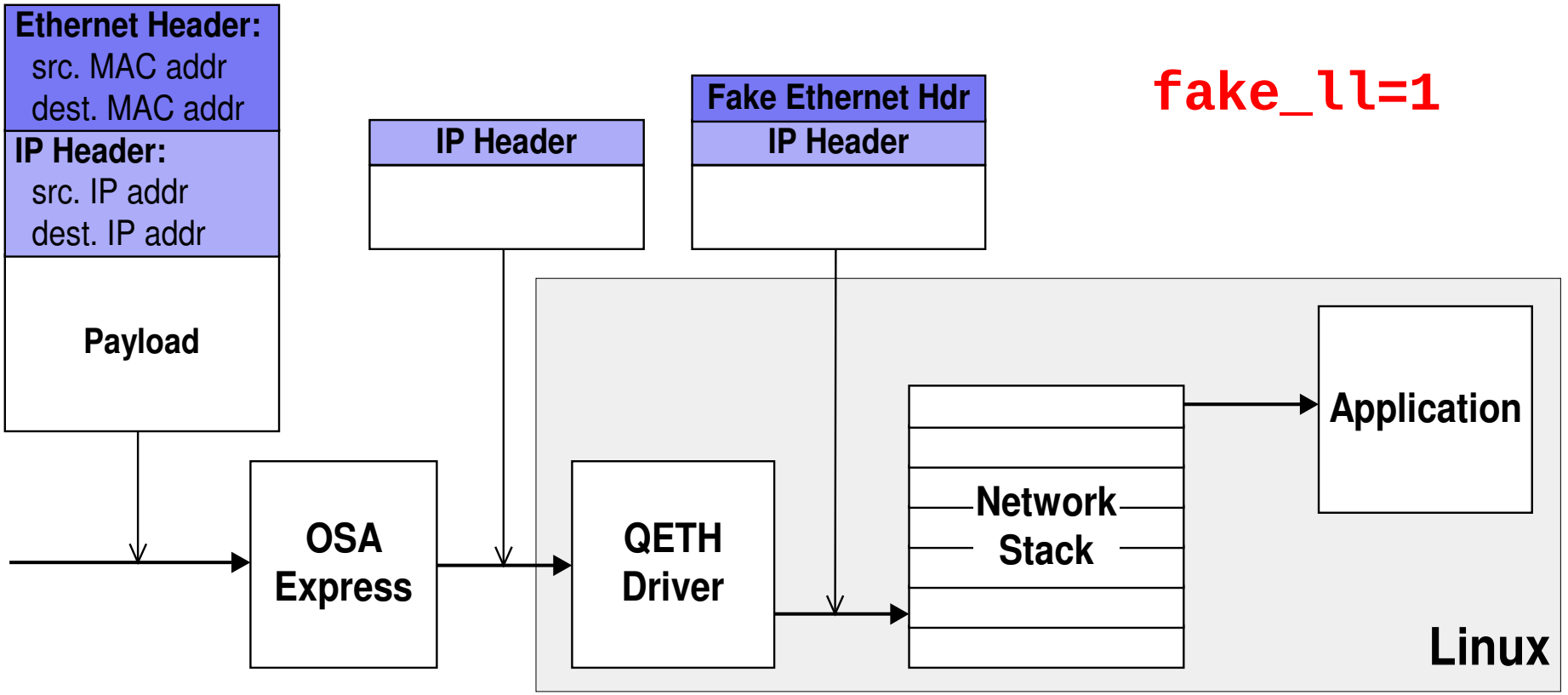
```
#> cat /proc/qeth
devices                          CHPID interface  cardtype
-------------------------------- ----- ---------- -------------- ...
0.0.c000/0.0.c001/0.0.c002 xC0   hsi0        HiperSockets
0.0.b003/0.0.b004/0.0.b005 x01    eth0        GuestLAN QDIO
```

7. Configure your new eth0 interface:

```
#> ifconfig eth0 10.2.1.2 netmask 255.255.0.0
```

QETH Device sysfs Attribute fake_ll

- Build fake ethernet headers before handing packets to the network stack.
- Required by some network applications, e.g. **DHCP** or TCPDUMP



QETH Device sysfs Attribute large_send

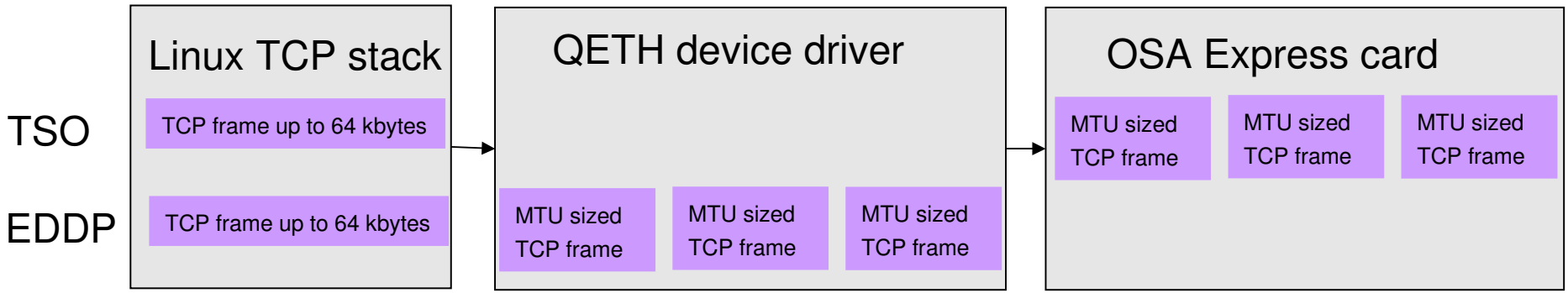
- Offload TCP segmentation from Linux network stack to OSA-card

```
QETH_OPTIONS='large_send=TSO'                    or
#> echo TSO > /sys/devices/qeth/0.0.b004/large_send
```

===> move workload from Linux to OSA-Express adapter

- Offload TCP segmentation from Linux network stack to device driver

```
QETH_OPTIONS='large_send=EDDP'                   or
#> echo EDDP > /sys/devices/qeth/0.0.b004/large_send
```



===> performance advantage with large outgoing packets

QETH Device sysfs Attribute check_summing

- Offload checksumming for incoming IP packages from Linux network stack to OSA-card

```
QETH_OPTIONS='checksumming=hw_checksumming'
```
or

```
#> echo hw_checksumming > /sys/devices/qeth/0.0.b004/
   checksumming
```

- ===> move workload from Linux to OSA-Express adapter

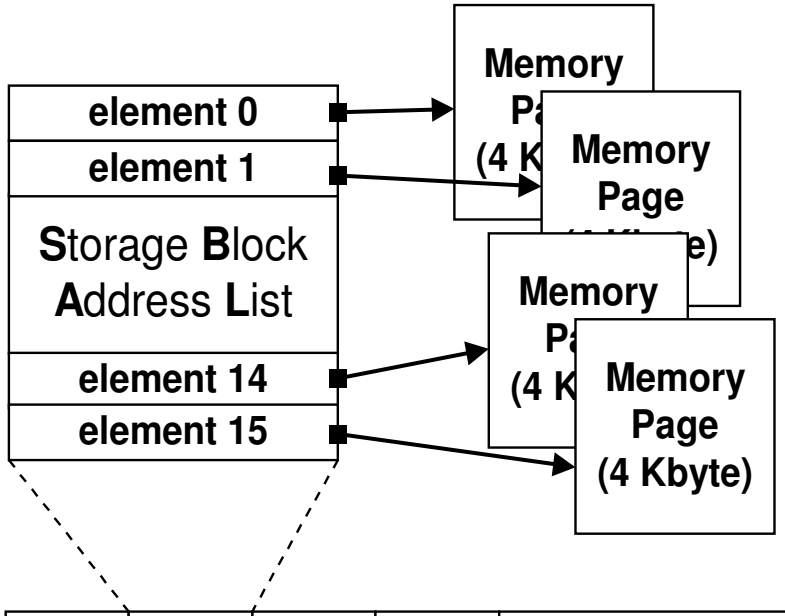
QETH Device sysfs Attribute recover

- enforce recovery of a qeth device

```
#> echo 1 > /sys/devices/qeth/0.0.b004/recover
```

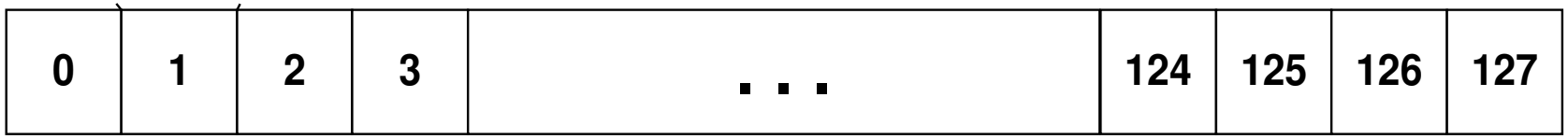
QETH Device sysfs Attribute buffer_count

- The number of allocated buffers for inbound QDIO traffic --> Memory usage.



Per QETH card memory usage:

control data structures:	~ 200 KB
memory for one buffer:	64 KB
buffer_count = 8	--> ~ 712 KB
buffer_count = 128	--> ~ 8.4 MB



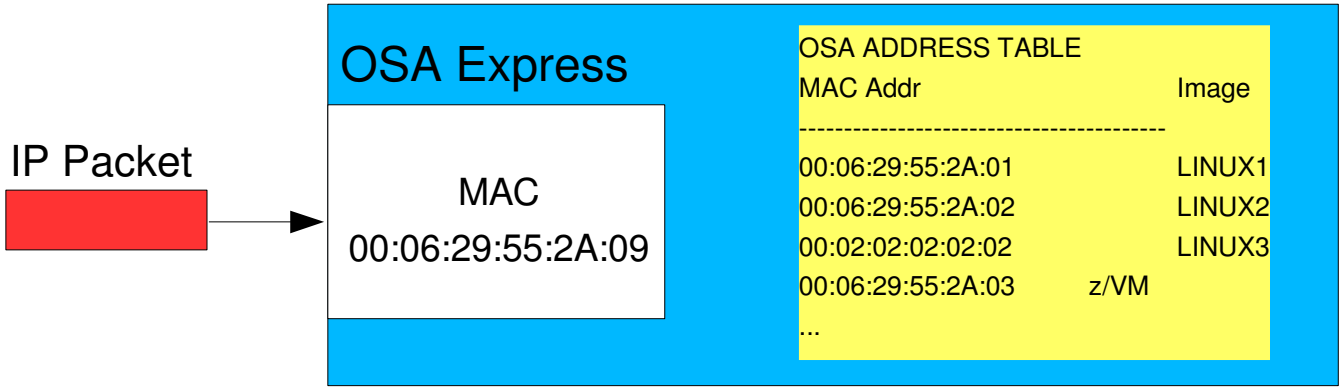
8 buffers **16 buffers (default, recommended)** **128 buffers**

Boost performance

Save memory

QETH Layer 2 mode

- OSA works with MAC addresses ==>no longer stripped from packets.



- **hwcfg-qeth... file (SLES10)** : `QETH_LAYER2_SUPPORT=1`
- **ifcfg-qeth... file (SLES10):** `LLADDR='<MAC Address>'`
- **ifcfg-... file (RHEL5):** `MACADDR='<MAC Address>'`
  `OPTIONS='layer2=1'`
- Direct attached OSA:
  MAC address must be defined with ifconfig manually
  `ifconfig eth0 hw ether 00:06:29:55:2A:01`
- with VSWITCH or GuestLAN under z/VM
  MAC address created by z/VM

QETH Layer 2 mode (cont.)

```
/sys
|--devices
   |--qeth
      |--0.0.<devno>
         |--layer2
```

- activating Layer 2 is done per device via sysfs attributes
- possible layer2 values:
  - 0: use device in Layer 3 mode
  - 1: use device in Layer 2 mode

- setting of layer2 attribute is only permitted when device is offline !
- DHCP, tcpdump working without option fake_ll
- channel bonding possible

QETH Layer 2 mode (cont.)

- Direct attached OSA
- GuestLAN type QDIO supported

  GuestLAN definition for layer2:

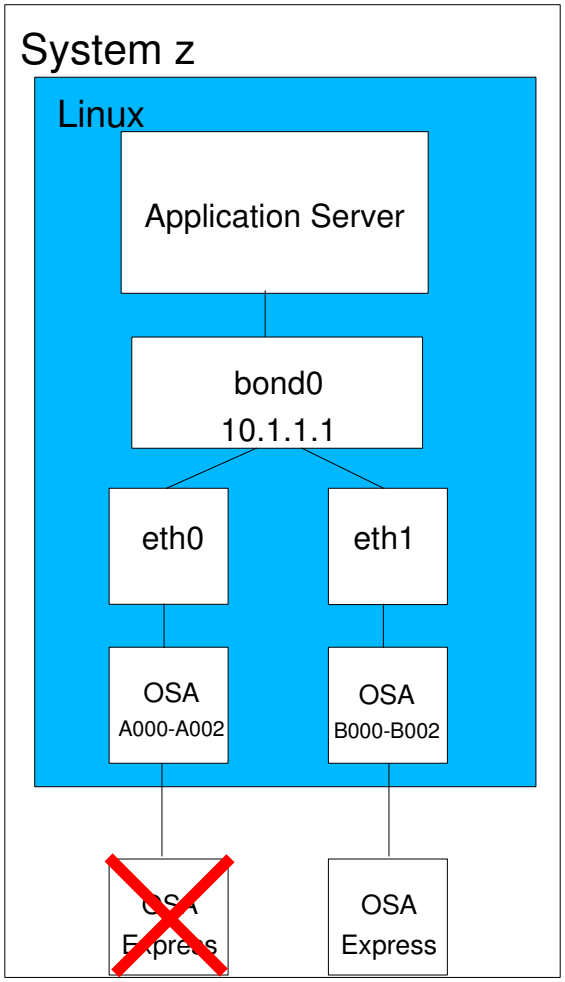
```
define lan <lanname> ... type QDIO ETHERNET
define nic <vdev> QDIO
couple <vdev> <ownerid> <lanname>
```

- VSWITCH

```
define vswitch <vswname> ... ETHERNET ...
define nic <vdev> QDIO
couple <vdev> <ownerid> <lanname>
```

- Restrictions:
  - Layer2 and Layer3 traffic can be transmitted over the same OSA CHPID, but not between two hosts sharing the same CHPID !

Channel Bonding



- The Linux bonding driver provides a method for aggregating multiple network interfaces into a single logical "bonded" interface
- provides failover and / or load-balancing functionality
- better performance depending on bonding mode
- transparent for LAN infrastructure
- latest setup description:

  http://sourceforge.net/projects/bonding/

Channel bonding setup

- Add MAC address to eth0 & eth1 (not necessary for GuestLAN or Vswitch)

```
#> ifconfig eth0 hw ether 00:06:29:55:2A:01
#> ifconfig eth1 hw ether 00:05:27:54:21:04
```

- Load bonding module with miimon option

  (otherwise bonding will not detect link failures)

```
#> modprobe bonding miimon=100 mode=balance-rr
```

- Bring up bonding device bond0

```
#> ifconfig bond0 10.1.1.1 netmask 255.255.255.0
```

- connect eth0 & eth1 to bond0

```
#> ifenslave bond0 eth0
#> ifenslave bond0 eth1
```

Channel bonding setup (SLES10 – config files)

- interface configuration file for a slave

```
/etc/sysconfig/network/ifcfg-qeth-bus-ccw-0.0.a000
   BOOTPROTO='static'
   IPADDR=''
   SLAVE='yes'
   STARTMODE='onboot'
```

- interface configuration file for a master

```
/etc/sysconfig/network/ifcfg-bond0
   BOOTPROTO='static'
   BROADCAST='10.1.255.255'
   IPADDR='10.1.1.1'
   NETMASK='255.255.0.0'
   NETWORK='10.1.0.0'
   STARTMODE='onboot'

  BONDING_MASTER='yes'
   BONDING_MODULE_OPTS='mode=1 miimon=1'
   BONDING_SLAVE0='qeth-bus-ccw-0.0.a000'
   BONDING_SLAVE1='qeth-bus-ccw-0.0.b000'
```

Channel bonding setup (cont.)

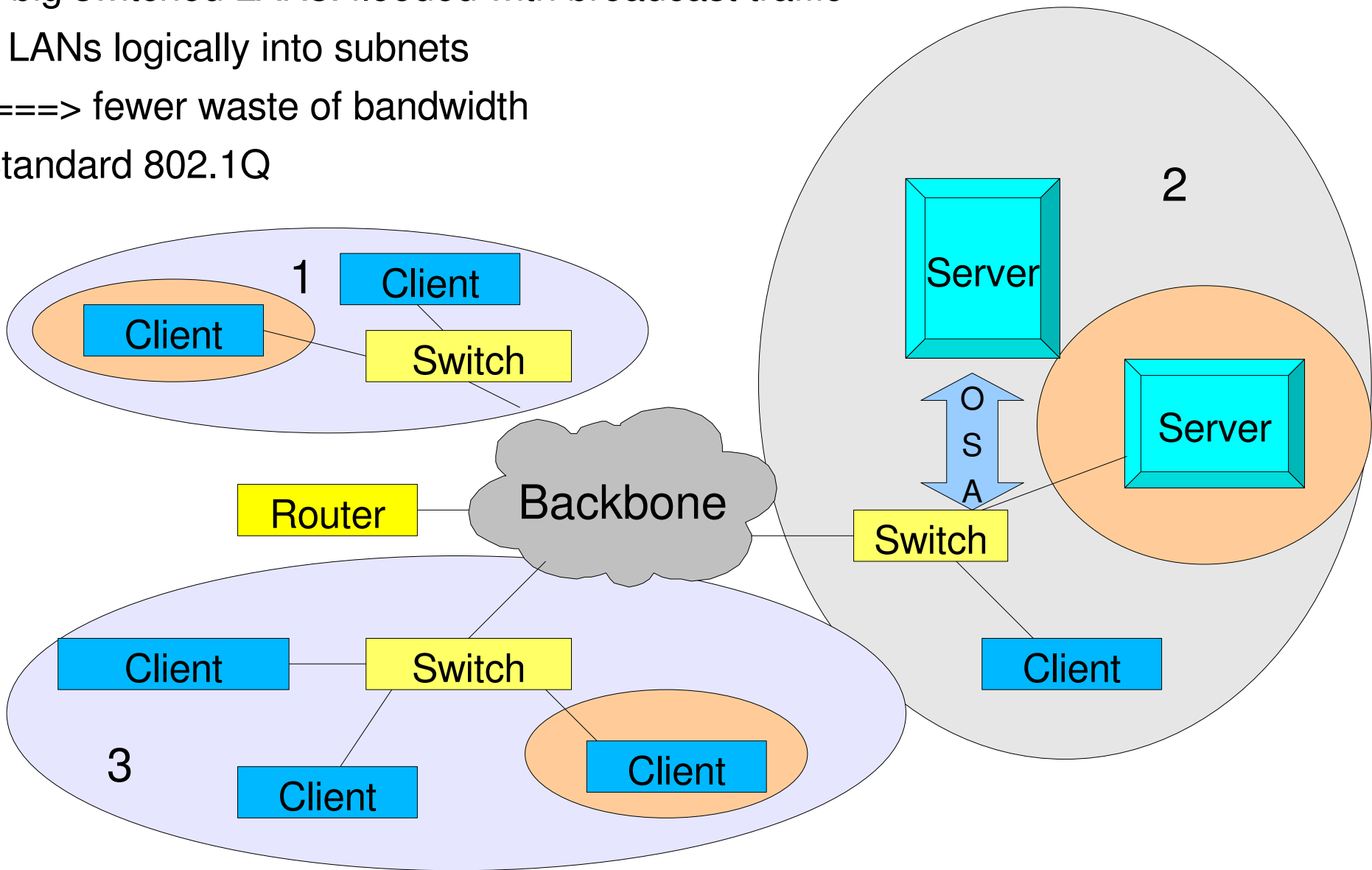
```
#> ifconfig
bond0     Link encap:Ethernet  HWaddr 00:06:29:55:2A:01
          inet addr:10.1.1.1  Bcast:10.255.255.255 ...

eth0      Link encap:Ethernet  HWaddr 00:06:29:55:2A:01
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500...

eth1      Link encap:Ethernet  HWaddr 00:06:29:55:2A:01
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500 ...
```

```
#> cat /proc/net/bonding/bond0

Bonding Mode: load balancing (round-robin)
MII Status: up
MII Polling Interval (ms): 100

Slave Interface: eth0
MII Status: up
Permanent HW addr: 00:06:29:55:2A:01

Slave Interface: eth1
MII Status: up
Permanent HW addr: 00:05:27:54:21:04
```

Virtual LAN (VLAN) support

- Risk of big switched LANs: flooded with broadcast traffic
- Devide LANs logically into subnets

  ===> fewer waste of bandwidth
- IEEE Standard 802.1Q



Virtual LAN (VLAN) support (cont.)

- Setup:

```
ifconfig eth1 9.164.160.23 netmask 255.255.224.0
vconfig add eth1 3
ifconfig eth1.3 1.2.3.4 netmask 255.255.0.0
```

- Displaying info:

```
cat /proc/net/vlan/config
VLAN Dev name    | VLAN_ID
Name-Type: VLAN_NAME_TYPE_RAW_PLUS_VID_NO_PAD
eth1.3           | 3  | eth1
```

- Implemented:

  VLAN tag, added to packets transmitted

- Supported by:

  real OSA-card, z/VM Guest LAN, z/VM VSWITCH

Interface names

Interface Name	Device Driver	Interface / Link Type	Model / Submodel	Used for
eth<x>	qeth lcs lcs	Ethernet	1731/01 3088/01 3088/60	OSA-card / type OSD P390-LCS-card OSA-card / type OSE
hsi<x>	qeth	Ethernet	1731/05	HiperSockets / type IQD
tr<x>	qeth lcs lcs	Token Ring	1731/01 3088/01 3088/60	OSA-card / type OSD P390-LCS-card OSA-card / type OSE
osn<x>	qeth	SNA<->Ethernet	1731/06	OSA-card / type OSN
ctc<x>	ctc	Point-to-Point	3088/08 3088/1e 3088/1f virtual	Channel-To-Channel adapter FICON adapter ESCON adapter VM-guest communication
iucv<x>	netiucv	Point-to-Point	virtual	VM-guest communication

Summary of Linux Network Device Drivers

	QETH				LCS	CTC	IUCV
	OSA	HiperSockets	GuestLAN QDIO	GuestLAN Hiper			
Adapters	100 Mbps, 1Gbps, 10Gbps1000 Base-T, HSTR				100 Mbps, 1000 Base-T, HSTR	ESCON, FICON, Virtual CTC/A	
Connection type	LAN	LAN	LAN	LAN	LAN	point-to-point	point-to-point
Layer	Layer2 / 3	Layer3	Layer2 / 3	Layer3	Layer3		
Protocols	IPv4, IPv6	IPv4	IPv4, IPv6	IPv4	IPv4	IPv4	IPv4
Remarks	**Primary network device driver for Linux on System z**				restricted access (admin defines OSA Address Table)	Deprecated in LINUX 2.6	

References

- Linux on System z on developerWorks
  http://www-128.ibm.com/developerworks/linux/linux390/index.html

- Linux on System z Documentation
  http://www-128.ibm.com/developerworks/linux/linux390/october2005_documentation.html

- Linux on System z, useful add-ons
  http://www-128.ibm.com/developerworks/linux/linux390/useful_add-ons.html

- Linux on System z – Tuning Hints & Tips
  http://www-128.ibm.com/developerworks/linux/linux390/perf/index.html